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Abstract

A HCFC 22/142b mixture can be used as a substitute for CFC 12 in a number of existing plants that are hardly convertible for use with HFC 134a. Comparative tests of these three fluids have been made. Lastly, the mixture distillation has been evidenced on a plant with recirculation type evaporator.

Introduction

Owing to the will to keep our biosphere properly balanced, the States are bringing industrial activities under regulation. The production of CFCs and their imports in the European Union are prohibited as from January 1st, 1995. CFC 12 is widely used in industry for heat generation up to 70°C (heat pumps or simultaneous heat and cold production). Though it has now been established that HFC 134a is a fluid which can replace CFC 12 [1] in the new installations, this will not always be true for the existing ones as the substitution which depends on the installation configuration can prove critical and exaggerately costly.

The use of an adequate HCFC mixture in such cases can be advantageous.

A Zeotropic Mixture For Existing Installations

Using a different refrigerant without substantial modifications of the installation needs a substitution fluid with thermodynamic characteristics close to those of CFC 12. This is profitable only if the lubricant must not be replaced : the substitution fluid must be compatible with lubricants currently used with CFC 12. These conditions can be fulfilled with an adequate HCFC 22/HCFC 142b [2] mixture, those fluids being well known and currently used.
This mixture contains 60% of HCFC 22 and 40% of HCFC 142b. It is non-flammable and its characteristics are close to those of CFC 12 when saturated (under 1 bar, its bubble and dew points being respectively -32.3°C and -23.2°C whereas CFC 12 saturation temperature is - 9.8°C).

The calculations for thermodynamic cycles prove that this mixture can replace CFC 12 in most cases [3] though real performance tests are necessary to confirm it. It seemed also interesting to make tests using HFC 134a for comparing the two solutions.

Operating Characteristics And Performances On The Test Plant

Tests have been carried out on a heat pump with dry expansion evaporator, to determine induced modifications following the replacement of CFC 12 by substitution fluids.

The installation is equipped with a four-piston reciprocating open compressor which sweeps a volume of 96.98 $m^3.h^{-1}$ at 1500 RPM. With CFC 12 and HCFC 22/142b, a poly-α-olefin type, ISO 100 grade lubricant with a viscosity index of 96 has been used, and, with HFC 134a, a polyol ester type, ISO 100 grade lubricant with a viscosity index of 148 has been used. Both evaporator and condenser are brazed plate heat exchangers (exchange area : 4.86 m^2). The evaporator incorporates a distribution element. A subcooler is mounted on the liquid line. The expansion valve is piloted by an electronic device which ensures constant superheat at suction. Water is used as a heat carrier in the three heat exchangers.

Adjusting the water flow rate and temperature allows various thermal conditions to be obtained.

Similar tests have been carried out for the three fluids :

- At condenser outlet, the water temperature has been set at 55, 60 and 65°C for a flow rate of 5 $m^3.h^{-1}$.
- At evaporator outlet, the water temperature has been set at 5, 10 and 15°C for a flow rate of 5 $m^3.h^{-1}$.
- The condensed refrigerant is subcooled down to a temperature lower than that at condenser water outlet by 5 K.
- The compressor rotates at its nominal speed (1500 RPM).

The heating and refrigerating power is calculated from the measured water flow rate and inlet and outlet temperatures at condenser, and evaporator. The coefficient of performance represents the heating power by mechanical power quotient. The mechanical power is calculated from the torque and speed measured between the motor and the compressor.

The discharge temperature when using HCFC 22/142b is too high for a production of hot water at 65°C. The three corresponding tests have consequently not been mentioned.

All the comparisons are made relative to CFC 12. With regard to HCFC 22/142b, speaking of phase shift temperature means the average bubble and dew points.

With HFC 134a, the discharge pressure (figure 1) is higher by 0.93 to 1.60 bar whereas it would be higher by 1.91 bar given a same condensation temperature ; these values are 1.33 to 1.67 bar and 1.14 bar respectively for HCFC 22/142 b. These deviations are supposed to be due to the heat exchange quality. We get HFC 134a, CFC 12, HCFC 22/142b in a decreasing order for condensation exchanges.

The suction pressures are lower by 0.27 bar for HFC 134a, and by 0.23 bar for HFC 22/142b. On the average and given a same evaporation temperature, these deviations would be 0.13 bar and 0.16 bar. Heat exchanges should thus be slightly better when using CFC 12 under evaporation conditions.

Consequently, the compression ratios are higher by 0.83 for HFC 134a and by 0.87 for HCFC 22/142b on the average (figure 2).

The discharge temperatures (figure 3) are lower by 7 K for HFC 134a and higher by 15 K for HCFC 22/142b on the average. The deviations would be 6 K and 18 K respectively for theoretical cycles given identical phase shift temperatures and isentropic efficiency.

For cold production at 15°C, HCFC 22/142b additionally supplies 8% of the cooling power and 11% of heating power. At 5°C, these powers drop by 13% and 7% respectively. They are equivalent at 15°C with HFC 134a but fall by 6% at 5°C.

The cold production temperature plays also an important part in the coefficients of performance : at 15°C, they are higher by 3% and 4% with HFC 134a and HCFC 22/142b, and, at 5°C, HFC 134a performance coefficient is higher by 1% and that of HCFC 22/142b lower by 2%.

Figure 4 shows the heat generation and the coefficient of performance. HCFC 22/142b thus enables the heating power and the performance coefficient to raise under the most favourable conditions (low temperature on the hot side, and high temperature on the cold side); under more stringent conditions, both the heating power and the performance coefficient are reduced. HFC 134a heating power is lower with a higher or equivalent performance coefficient. The heating power is practically identical under the best operating conditions.

Distillation Of The Zeotropic Mixture With Recirculation Type Evaporator Plant

The above results are obtained with a dry expansion evaporator plant. As the HCFC 22/142b mixture is rather zeotropic (9.1 K between the bubble and dew points under 1 bar), in plant with recirculation type evaporator, the less volatile fluid tends to stay in the low pressure liquid. This is why tests have been carried out on such a plant equipped with a single-screw compressor sweeping a volume of 311 $m^3.h^{-1}$, a plate-type evaporator of 18.24 m^2 fed through a recirculation pump, a 80 m^2 shell-and-tube condenser. This configuration is representative of that of a number of industrial plants.

Tests have been performed at two different temperature conditions : mean condensation at 45°C, evaporation (low pressure receiver temperature) at -15°C (skating rink), and 5°C, 60°C (malt houses). After stable operating conditions had been established, a liquid sample has been taken from high pressure and low pressure receivers for further analysis.

When used in skating rinks conditions, the LP (low pressure) liquid contains 44.9% of HCFC 22 and the HP (high pressure) liquid 74.1% ; the LP liquid represents 48% of the refrigerant mass.

In malt houses conditions, LP and HP liquids contain 44.8% and 71.4% of HCFC 22 respectively (43% of the load as LP liquid).

These changes in the concentration are worth being taken into consideration as they make the high pressure rise by 1.71 bar for skating rinks and by 1.89 bar for malt houses compared with the direct expansion. The low pressure remains however unchanged in both cases.

Conclusion

A HFC 134a mixture has been successfully tested on a dry expansion evaporator heat pump fitted with a reciprocating compressor, for use in existing installations which would hardly be capable of using HFC 134a.

The operating conditions are close to those for CFC 12 and HFC 134a. It was however impossible to use the mixture at a high temperature owing to the high discharge temperature, which becomes feasible when cooled-lubricant screw compressors are used.

The mixture is fairly highly zeotropic and tests have proven that the distillation must be taken into account in recirculation plants to use a load with a well-suited composition.

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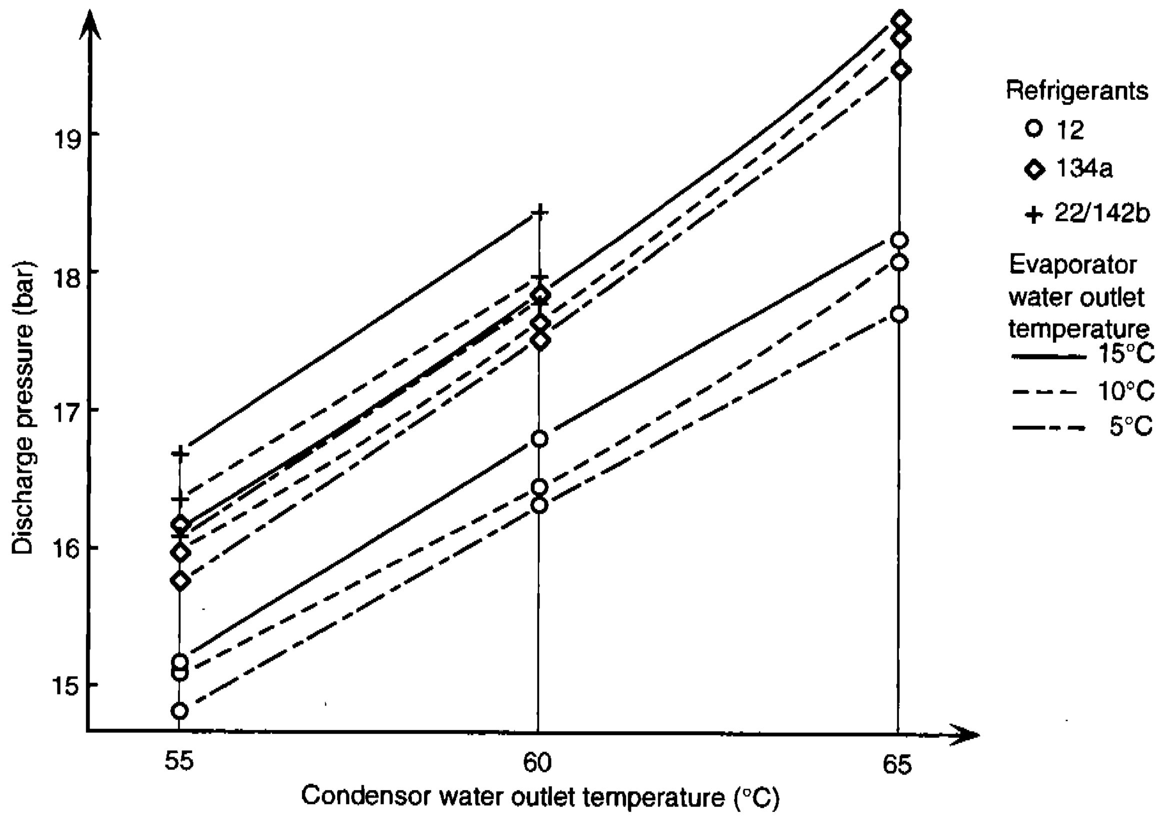

Figure 1 : Discharge pressure for different running conditions

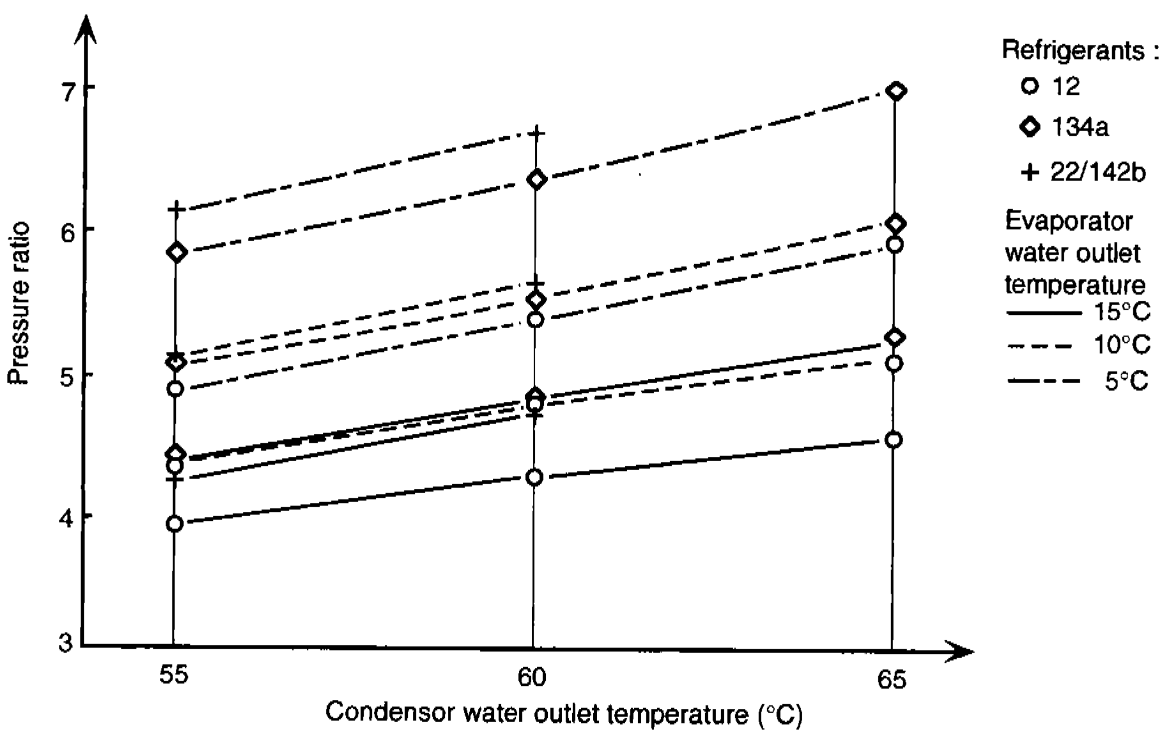

Figure 2 : Pressure ratio for different running conditions

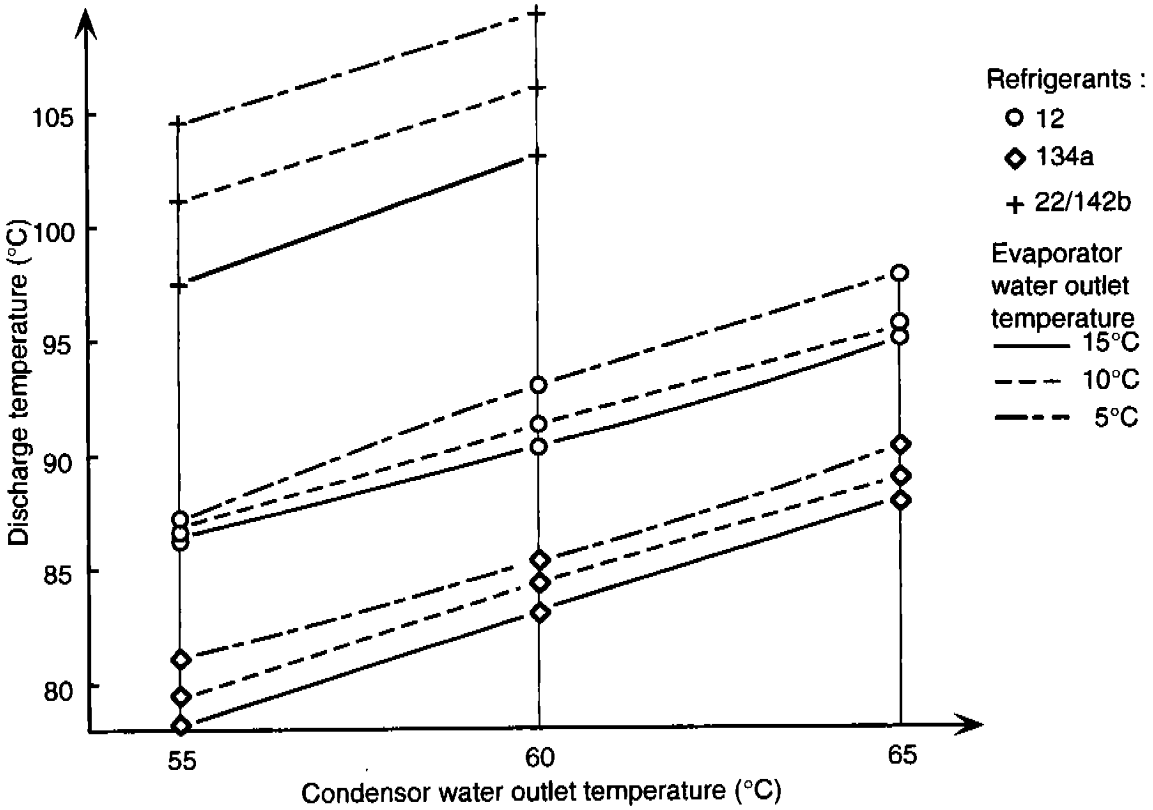

Figure 3 : Discharge temperature for different running conditions

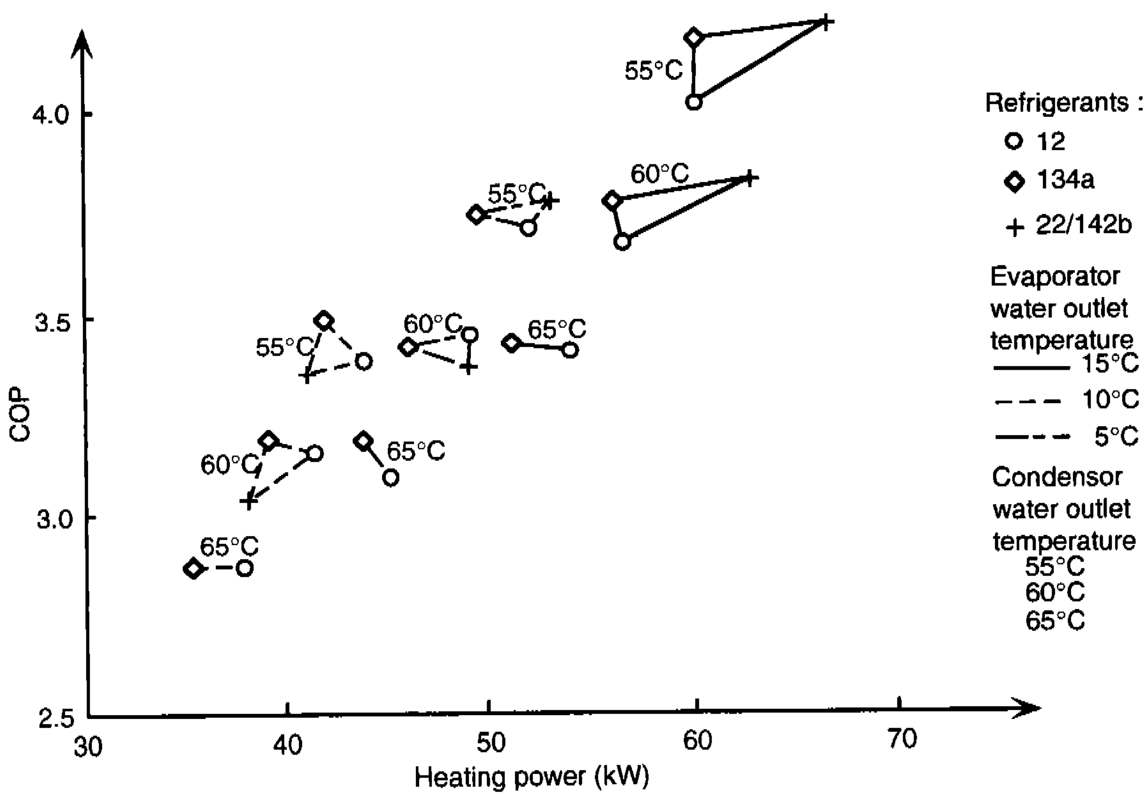

Figure 4 : Performance and heat production for the different running conditions